APPENDIX I

DETROIT RIVER SEDIMENT TOXICITY

INTERIM REPORT TO
U.S. Environmental Protection Agency
Office of Research and Development
Environmental Research Laboratory - Duluth, Minnesota
Large Lakes Research Station - Grosse Ile, Michigan

DETROIT RIVER SEDIMENT TOXICITY

by

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September 25, 1987

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Submitted to:

Journal of Great Lakes Research

Submission Date Here

RUNNING HEAD: DETROIT RIVER SEDIMENT TOXICITY

ABSTRACT

We used the Photobacterium phosphoreum bacterial luminescence assay (Microtox^{R}) to survey the distribution of the toxicity of the sediments from the lower Detroit River during the summer of 1986. Of the 136 locations tested, 25 were found to be very toxic; 60 were moderately toxic; 10 were slightly toxic and 41 were classified as being non-toxic. The greatest number of very toxic sites were observed on the western shore of the Trenton Channel, however some very toxic locations were observed throughout the study area. The least toxic areas were observed on the eastern most locations studied. The utility of the Microtox^{R} assay for rapid screening and mapping of toxicity of sediments is discussed as well as the relationship of this assay to other assays and the observed distribution of indigenous macroinvertebrates.

ADDITIONAL KEY WORDS: Metals, petroleum hydrocarbons, Microtox^{R}, bacteria, bioassay, Great Lakes.

INTRODUCTION

The densely populated, highly industrialized regions near the Great Lakes have resulted in many contaminated areas within the Great Lakes, (Bishop, 1987). The confined areas between the lakes, which have come to be know as the Upper Great Lakes Connecting Channels, are especially contaminated (Baker, 1980a; 1980b, Scrudato and DelPrete, 1982; Cmuska et al., 1983; Charlton, 1983; Glooschenko et al., 1976; Thomas and Mudroch, 1979). The Detroit River and the western basin of Lake Erie are heavily impacted by industrial and municipal wastes, urban and agricultural runoff (IJC, 1981). The Detroit River is a busy transportation artery which connects Lake Erie with Lake St. Clair. The channels are maintained by dredging and several areas, such as Fighting, Mud, Grassy, Zug and Grosse Ile Islands have been used to dispose of dredge spoils and industrial wastes. A summary of the existing status of these areas, relative to contamination has been given by Rodgers et al. (1985). A number of contaminants, including organic xenobiotics (Pranckevicius, 1986; Fallon and Horvath, 1985; Kaiser et al., 1985; Platford et al., 1985; Comba and Kaiser, 1985; Hamdy and Post, 1985) and metals (Pranckevicius, 1986; Fallon and Horvath, 1985; Hamdy and Post, 1985; Lum and Gammon, 1985; Maguire et al., 1985; Chau et al., 1985; Sly, 1983) have been found in

sediments of the Detroit River. Specifically, the concentrations of PCBs exceed objectives and criteria set by the Ontario Ministry of the Environment and International Joint Commission (Rodgers, 1985). Also, the mean total concentrations of metals in sediments for which there are criteria set by the USEPA; which are Cd, Cr, Hg, Ni, Zn, Cu, Ba, Fe, Pb and Mn; exceed the guidelines for heavily polluted areas (Pranckevicius, 1986; Anon, 1980). These contaminated sediments can be toxic to benthic organisms (Thornley and Hamdy, 1984; Munawar et al., 1983) as well as serve as a source of contaminants for redistribution (Scrudato and DeFrete, 1982).

Assessing the degree of contamination of sediments consists of basically two aspects, including: 1) what contaminants are present and 2) what are the potential effects of these contaminants on biota (Bishop, 1987). To determine the potential toxicity of sediments to benthic organisms one could conduct a survey to determine the number and types of indigenous organisms present (Chapman, 1986). While this is a technique, which has been much used, it suffers from several limitations. First, unless one can establish that all of the chemical and physical parameters, other than toxicants, and sources of colonizing individuals are the same from location to location, it is difficult to demonstrate that differences among populations are due to toxic substances in the sediments. A

number of short-term chemical and physical stressors can irradicate populations of benthic organisms without leaving toxic residues in the sediments. Also, present-absence data can not be used to assess the toxicity of deeper sediments, which are generally not colonized by benthic invertebrates.

Alternatively, sediment toxicity can be estimated from the concentrations of toxic substances associated with sediments. The completeness of these analyses are seldom known (Ballar et al., 1980; Hoke and Prater, 1980; Samolloff et al., 1983) as well as the actual availability of the toxicants to biota (Oliver, 1983, Ward and Young, 1984; Babich and Stotzky, 1977) and the interactions among toxicants.

Therefore, in surveying the community of benthic organisms and concentrations of toxic substances in sediments it has been suggested that rapid direct assessments of toxicants be determined by bioassays (Chapman, 1986). We used the reduction of bioluminescence of the bacterium Photobacterium phosphoreum (Microtox^{R} assay) by pore water extracts from 136 locations in the lower Detroit River, during the summer of 1986.

METHODS

SAMPLE COLLECTION

Samples of sediment were taken by "PONAR" dredge, from the lower Detroit River, during the summer of 1986. Sampling

stations were located by Loran-C and triangulation of local land marks. Each station was identified by a station number (Fig. 1.) and located by latitude and longitude coordinates. Aliquants of sediment were placed in glass bottles in the laboratory. where they were maintained at 4°C until they were processed.

Pore waters were extracted by a combination of centrifugation and filtration. Multiple 250g-subsamples of sediment were centrifuged in 250 ml containers, at 18,000 RPM (22,000 Xg RCF), for 45 min at 20°C. The supernatant was filtered through 4.25 cm diameter, 1.2 um nominal pore size, glass fiber filters (Whatman GF/C, 20 psi vacuum. Pore water was maintained at 4°C until they were used in assays (always less than seven days from the time of centrifugation).

MICROTOX^R ASSAY

The Microtox^R bacterial luminescence assay was performed on pore water extracts by standard procedures (Bulich, 1984; Qureshi et al., 1984; Indorato et al., 1984; Vasseur et al., 1984). Reduction in bioluminescence of the bacterium Photobacterium phosphoreum was measured with a Microtox^R Model 2055 Toxicity Analyzer (Microbics, Co., Carlsbad, CA.). We suspended the P. phosphoreum, to a cell density of 10^8 cells/ml, in 2% NaCl. Pore water was added to the mixture to

give final concentrations of 7.5, 15, 30 and 60% pore water in the NaCl medium. We determined the percent pore water in the incubation to cause a 10% (EC-10) or 50% (EC-50) reduction in bioluminescence, relative to control incubations (Table 1). We determined the dose-response relationships from the log-probit relationship (Finney, 1971); Stephan, 1977) with the PROBIT procedure or the Statistical Analysis System (SAS, 1985).

The pore water from some locations resulted in a slope of the log-probit regression, which was not significantly different from zero. These sediments were deemed non-toxic (Table 2). Also, the pore water of some sediments resulted in predicted EC-50 values, which were greater than 100%. Because these values were beyond the range of our experiment these sediments were also reported to be non-toxic. This does not mean that there was not some reduction in bioluminescence at these locations, but rather, that it would take a pore water extract of greater than 100% to cause a 50% reduction in bioluminescence. Therefore; our reporting of sediments is conservative and sediments classified as non-toxic by this assay may show some toxicity.

RESULTS

Of the 136 locations tested, 25 were found to have EC-10 values, which were less than 10% pore water extract. These

locations were classified as being very toxic. These locations were located, primarily, in the Rouge River and along the western shore of the Trenton Channel (Fig. 1 and Table 1). However, there were other locations, which were also found to be very toxic. Most of these were located in the main channel of the Detroit River, north of Grosse Ile. Several isolated locations, such as station Nos. 53, 183, 42 and 121 were found to have sediments, which exhibited great toxicity, as measured by the Microtox™ assay.

Sixty locations were classified as moderately toxic. That is, they had EC-10 values of greater than 10% and less than 40% pore water. Sediments, which exhibited this degree of toxicity, were observed throughout the lower Detroit River system, on both sides of Grosse Ile (Fig. 1).

A total of 10 locations yielded sediment pore water which exhibited EC-10 values of greater than 40% and less than 80% pore water. These samples were classified as slightly toxic.

Forty one of the 136 locations, sampled in our study, were found to be non-toxic. That is, they exhibited EC-10 values of greater than 80% pore water extract or had no significant slopes in the log-probit regression. The area along the western shore of Fighting Island, including station Nos. 82, 83, 130 and 136 represented a relatively large area of sediment, which was found to be non-toxic. The sediments from the eastern shore of the Trenton Channel were generally less toxic than those from the

western shore. We also found an area of non-toxic sediment in the Rouge River. In general, sediments from the eastern side of Grosse Ile were less toxic than those on the western side.

DISCUSSION

The Microtox^{R} assay is a bacterial luminescence bioassay developed by Beckman Inc. in 1977 (Bulich, 1984) as a rapid screening alternative to standard acute toxicity testing with fish or invertebrates. This test is based on the reduction of bioluminescence of the marine bacterium (Photobacterium phosphoreum) (NRRL B-11177) by toxicants. This test is simple and only requires 30 min. to complete.

The Microtox^{R} assay has been extensively studied and the results of this test compared to acute bioassays with both fish and invertebrates for a large number of pure compounds and complex mixtures (Bulich, 1984; Bulich et al., 1981; Curtis et al., 1982; Lebsack et al., 1981; Qureshi et al., 1982; Qureshi et al., 1984; Tarkpea et al., 1986; Schiewe et al., 1985; Indorato et al., 1984; Nacci et al., 1986; Vasseur et al., 1984; Hermens et al., 1985). These comparisons have demonstrated general agreement between toxicity values determined by the standard fish and Daphnia magna acute assays with that of the Microtox^{R} assay among-laboratories (Green et al., 1985).

The use of bacteria as surrogate assay organisms, is predicated on the assumption that at least some biochemical and physiological systems are evolutionarily conservative and that toxicants elecit observed effects due to interactions with biomolecules, which are similar in many different organisms. However, because of the differences in modes of action of toxicants and physiologies and biochemistries of organisms, one would not expect all organisms to respond similarly to a range of toxic chemicals. Some toxicants have specific effects on particular organisms or groups of organisms. For this reason bacteria, algae and animals may exhibit a differential sensitivity to organic and inorganic toxicants. When 156 pollutants were examined, 23 exhibited a pronounced selective toxic action on bacteria, while 47 were more toxic to algae and 43 had the greatest effect on protozoans (Bringmann and Kuhn, 1980).

Bacteria, in general, are equally sensitive or more sensitive to metals than are plant or animal cells (Babich and Stotzky, 1985). For instance, P. phosphoreum is much less sensitive to both mercury and cadmium than is D. magna (DeZwart and Slooff, 1983). Bacteria are, however, not insensitive to all metals. Marine bacteria such as P. phosphoreum, are particularly sensitive to the toxic effects of metals such as copper (Gillespie and Vaccaro, 1978; Sunda and Gillespie, 1979). Based on the observed concentrations of metals in some Detroit River sediments (Pranckevicius, 1986; Fallon and

Horvath, 1985; Thornley and Hamdy, 1984) it is likely that the metals were responsible for a large amount of the observed toxicity of pore water.

Bacteria have generally been thought to be tolerant of pollution by petroleum hydrocarbons (Adams, 1985). However, bacteria can be inhibited by exposure to crude oils (Hodson et al., 1977).

Bacteria are known to be very tolerant of some organic compounds, which are extremely toxic to crustaceans. For instance, Malathion has an LC-50 for D. magna of 1.8 ug/l while a solution of 1% actually promotes growth of some bacteria (Jonas et al., 1984). Lindane is approximately 300 times more toxic to guppies than to P. phosphoreum (Hermens et al., 1985). Thus, for Lindane, some inhibition would be observed in the Microtox^{R} assay but this would underestimate the effects of Lindane on higher organisms. Also, the commonly used herbicides Simazine and Endothall had no effects on number or function of aquatic bacteria but have drastic effects on algae and aquatic angiosperms (Beckman et al., 1984). Thus, the results of the Microtox^{R} test would underestimate the effects of these compounds on aquatic plants as well as some fish and invertebrates. Bacteria are also not very sensitive to many other chlorinated compounds, such as solvents, PCBs and insecticides. For example, PCBs, which are a common contaminant in the lower Detroit River, are not very toxic to most bacteria

(Vitkus et al., 1985). Therefore, the Microtox^{R} assay would not be very sensitive to toxic effects of PCBs and similar compounds. The Microtox^{R} assay is not very sensitive to extremely lipophilic organic compounds. A deviation from the log EC-50 vs. log-P relationship for P. phosphoreum occurs at a log-P of 3.0 and greater.

This deviation is not observed for the same relationship in bioassays with fish, such as the guppy (Hermens et al., 1985). Alternatively, bacteria are known to be much more sensitive to some organic compounds such as antibiotics (DeZwart and Slooff, 1983). Because of this type of variation in sensitivities among compounds, and deviation from the responses of higher organisms, the use of microbial bioassays for rapid assessment of sediment has not been widely accepted. Rather, it has been suggested that sediment microbial activity should be used as part of a battery of assays for assessing the toxicity of sediments (Bedford et al., 1986; Chapman et al., 1982; Archibald, 1982; Munawar et al., 1984; Obst, 1985).

Given the above discussion, what is the justification for using the Microtox^{R} assay as a rapid screening assay for the toxicity of sediments? In a concurrent study of the toxicity of 30 of the same sediments studied here, Giesy et al. (1987) compared the inhibitory effects of pore water in the Microtox^{R} test to the lethality of Daphnia magna and the effects of the whole sediment on growth of larvae of the dipteran midge

Chironomus tentans (Giesy et al., 1987). In that study, while the results of the three assays were not completely congruent, it was established that the most toxic and non-toxic locations were well discriminated by the Microtox^{R} assay. Furthermore, there were correlations and predictive relationships which could be established among the three assays. Giesy et al. (1987) report that an EC-10 value of 25% pore water in the Microtox^{R} assay causes a 30% reduction in the growth of C. tentans and corresponds to the degree of toxicity, above, which they observed no benthic insects (Giesy et al. 1987). Therefore, all of the 85 locations, which were classified as very or moderately toxic were too toxic to support benthic insects.

We are aware of only one other study, which has used the Microtox^{R} assay to investigate the toxicity of sediments (Schiewe et al., 1985). This study differed from ours, in that, the toxicity of methanol-dichloromethane extracts of sediment, which had been solvent-exchanged into ethanol were tested instead of pore water. When solvent extracts were used, a statistically significant positive correlation was observed between reduction in bioluminescence of P. phosphoreum and the concentrations of aromatic and chlorinated hydrocarbons (Schiewe et al., 1985). This indicates that the Microtox^{R} assay is sensitive to these compounds and that these classes of compounds could have been responsible for some of the observed toxicity of Detroit River sediments since several locations had great

concentrations of polycyclic aromatic hydrocarbons (PAH) (Pranckevicius, 1986; Fallon and Horvath, 1985; Kaiser et al., 1985).

Areas, which we determined to be non-toxic had viable populations of aquatic, benthic invertebrates which have been reported in the literature (Thornley and Hamdy, 1984) and were corroborated by our own observations. The organisms, which were found to be present, included several pollution-sensitive taxa, such as: Hexagenia limbata and Hyallela sp. The greatest populations of organisms were observed on the eastern bank of the Detroit River, in Canadian waters.

Healthy populations of benthic invertebrates were observed adjacent to extensively contaminated areas. The current of the river is so great that contaminants are kept near the bank, from which they are discharged and do not seem to be deposited across the river. Therefore, it is possible to have healthy populations of benthic invertebrates directly across the channel from where the contamination is so great that we observed no benthic invertebrates. This was the case at station Nos. 118 and 30AC, which were on the east side of the Trenton Channel, directly across from station Nos. 30UP, 30CR and 30, which were areas which had the most toxic sediments (Fig. 1). Similarly, further south in the Trenton Channel, we observed very toxic sediments at station Nos. 34, 120, 105, 106, 107 and 145. However, directly east of these locations, on the east shore of

the Trenton Channel, we observed no toxicity at station Nos. 131 or 41.

Extensive surveys of the chemical constituents of the sediments, which caused the greatest toxic effects in our assays have been conducted by the U.S. Environmental Protection Agency (Pranckevicius, 1986). These studies have revealed great concentrations of metals, PCBs, and other industrial organic chemicals and PAH. The concentrations of many toxicants exceed existing sediment quality criteria. Similarly, the Ontario Ministry of the Environment (Thornley and Hamdy, 1984) reported metal concentrations, which exceeded sediment quality criteria.

We observed areas of greatest sediment toxicity to be grouped together. This indicates that there are or have been point sources, responsible for the sources of the toxicity This conclusion is further supported by the gradient in sediment pore water toxicity, which was observed along the Trenton Channel below station No. 30UP. The maximum sediment toxicity was observed adjacent to the Federal Marine Terminal (FMT) hazardous waste site. Eight of the most toxic sediments were observed at this site or within a distance of one kilometer below this location. Immediately above this site the sediment was found to be only moderately toxic, even through the sediment had a similar physical appearance. This indicates that the source of the toxicity is in the vicinity of the FMT site, which is located in Riverview, Michigan, adjacent to the Trenton

Channel. The 30 acre site was purchased by the BASF, Wyandotte Chemical Company in 1951 and used as a landfill for chemical/industrial materials until 1979. The result of these activities was a site which had a 10-15 ft thick zone of hazardous material, covered by sandy soil and swamp sediments. In December of 1979 it was determined that the subsurface water at the site was very contaminated and that the groundwater was moving from east to west and into the Detroit River at a rate of $1.5X10^{-5}$ CFS. It was also determined that at least some toxic materials, which were known to be buried in the site were occurring at greater concentrations in sediments below than above the site. The site was secured by stabilizing the beach, covering the site and installing a system of monitoring wells.

Huntington Creek (also known as Monguagun Creek) has been suggested as a source of contamination for the east side of the Trenton Channel. While sediments from the creek are toxic, they are less toxic than sediments above and below the creek in the Detroit River. This suggests that the source of the toxicity is not Huntington Creek alone. Subsequent chemical determinations will be required to ascertain the cause of the toxicity and the source of the toxicant.

CONCLUSIONS

The Microtox^{R} assay allowed us to quantify the toxicity of sediments rapidly. Also, the assay allowed us to investigate the potential toxicity of sediments, where organisms did not occur because of sediment type or physical parameters, such as oxygen, current or depth of sediment. The assay also provided a dose-response relationship which offered more information than presence or absence of benthic invertebrates. This information can then be used to determine the potential for toxicity due to translocation of sediments to other locations. The information will also allow the determination of how near or far the toxic potential of sediments is from that which would restrict colonization by animals.

The results of our survey indicate that there are sediments in the lower Detroit River, which are extremely toxic. While most of the very toxic sediments are along the western portion of our study area, locally very toxic sediments were found throughout the lower Detroit River. However, we also found areas at which the sediments were not toxic and suggested populations of benthic insects.

Table 1. Inhibition of P. phosphoreum bioluminescence (Microtox^{R}) by pore water extracts from Detroit River sediments.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
106	0.1	0.05- 0.07	6.0	5.6 - 6.4
30UP	0.4	0.32- 0.45	5.9	5.0 - 7.0
112	0.4	0.36 0.47	15.2	14.6 15.9
119	1.2	0.78- 1.8	5.8	5 0 - 6.8
188	2.2	1.9 - 2.4	30.5	26.8 - 41.9
25	2.8	2.4 - 3.2	35.2	30.9 - 41.5
30CR	2.8	2.5 - 3.1	22.9	22.2 - 23.8
34	3.0	2.6 - 3.5	20.7	19.6 - 21.7
157	4.8	3.6 - 6.2	155.2	110.1 - 218.8
147	5.0	4.94- 4.96	32.5	30.9 - 34.3
204	5.5	4.4 - 6.9	132.6	99.4 - 176.8
127	6.5	5.0 - 8.5	160.5	106.9 - 240.9
165	8.9	7.4 -10.8	69.2	54.9 - 87.2
42	9.3	8.2 -10.6	100.5	82.7 - 122.5
105	9.6	7.5 -12.3	59.3	44.6 - 79.0
167	9.8	7.5 -12.8	73.2	50.9 - 105.2
53	9.9	8.0 -12.2	789.4	397.8 - 1566.0
107	10.4	8.6 -12.5	154.9	97.9 - 245.2
162	10.9	8.0 -14.9	206.4	99.1 - 448.3
203	11.0	10.0 -12.1	150.5	124.5 - 181.9
183	11.5	8.9 -14.9	78.9	52.5 - 118.7

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
198	11.8	8.6 -16.2	158.7	77.8 - 323.6
120	11.9	11.1 -12.8	96.6	85.7 - 108.9
124	13.1	9.9 -17.3	693.2	168.8 - 2847.2
30	13.2	11.4 -15.2	64.3	45.3 - 91.3
43	13.8	12.4 -15.5	157.9	120.4 - 207.1
145	14.2	12.4 -16.3	67.1	53.7 - 83.9
144	14.6	10.9 -19.5	163.9	99.5 - 270.1
161	15.4	11.7 -20.3	107.7	58.7 - 197.6
209A	16.3	11.7 -22.7	138.2	57.5 - 332.1
137	16.4	13.9 -19.4	131.5	87.6 - 197.4
143	16.9	14.3 -19.9	133.6	87.9 - 203.0
189	17.5	14.4 -21.2	220.3	121.7 - 398.9
211	17.6	14.6 -21.2	85.6	58.7 - 124.8
191	17.8	16.1 -19.7	137.0	105.7 - 177.6
227	18.2	15.1 -21.9	400.9	193.5 - 830.8
20A	18.4	15.2 -22.2	95.0	62.4 - 144.6
121	19.2	17.0 -21.7	119.3	58.2 - 244.7
186	19.8	14.2 -27.6	108.3	47.1 - 248.9
155	19.8	18.9 -20.8	140.9	124.5 - 159.5
110	19.9	15.9 -24.8	786.6	262.0 - 2358.6
163	21.2	15.7 -28.5	148.2	95.3 - 230.4

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
37	21.7	19.0 -24.8	433.5	324.1 - 580.1
128	22.2	14.6 -33.9	245.9	98.4 - 614.7
166	22.3	15.7 -31.7	559.8	126.5 - 2477.4
159	22.4	16.3 -30.8	150.7	58.9 - 385.4
207	22.6	20.2 -25.2	145.1	103.5 - 203.4
135	22.8	19.4 -26.4	236.2	161.8 - 344.9
117	23.1	20.4 -26.1	252.7	167.3 - 379.7
49	23.1	18.3 -28.3	132.0	77.4 - 225.3
77	23.9	16.8 -34.2	1000.0	145.4 -10969.0
196	24.0	16.3 -35.3	751.5	97.0 - 5822.8
45	24.0	21.4 -27.0	56.7	43.5 - 73.8
172	24.1	18.5 -31.2	317.9	118.2 - 855.1
154	25.8	33.6 -35.5	108.6	50.4 - 233.9
160	26.8	19.1 -37.6	216.4	74.8 - 625.7
104	28.3	23.9 -33.5	184.3	95.1 - 357.1
153	28.4	23.6 -34.3	588.1	266.6 - 1297.2
170	29.9	22.4 -39.9	165.4	73.1 - 374.1
202B	30.4	17.8 -51.8	71.6	25.9 - 197.6
214	30.4	25.2 -36.6	132.0	85.1 - 204.7
52	30.4	26.7 -34.7	520.3	310.8 - 871.0
208	30.5	19.4 -48.1	110.1	37.8 - 320.9

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
202	30.8	18.7 - 50.7	167.7	22.2 - 1265.0
228	31.5	9.9 -100.4	218.2	0.93-51147.7
192	32.4	27.0 - 38.8	141.2	92.1 - 216.4
209	32.6	25.8 - 41.1	292.9	140.4 - 611.3
158	33.6	28.4 - 39.9	668.9	252.6 - 1770.9
126	33.7	21.0 - 54.3	107.4	43.6 - 264.5
212	36.1	27.3 - 47.8	130.8	71.6 - 239.0
59	38.1	31.6 - 45.9	186.7	119.6 - 291.5
197	38.4	23.0 - 64.2	201.4	26.8 - 1514.5
213A	38.8	30.4 - 49.6	146.4	38.2 - 257.7
190	40.9	31.5 - 53.2	224.2	91.3 - 550.7
182	41.3	33.7 - 50.7	332.3	186.8 - 591.2
146	42.7	26.8 - 68.0	160.1	58.5 - 436.8
133	44.5	35.1 - 56.5	263.8	118.3 - 588.3
152	44.5	35.1 - 56.4	229.1	124.6 - 421.1
218	46.2	30.5 - 69.9	125.7	49.1 - 321.8
222	46.4	13.4 -161.2	166.9	9.3 - 2981.7
151	46.7	38.4 - 56.7	513.2	229.8 - 1146.1
225	47.8	14.6 -156.2	141.5	12.2 - 1644.6
138	48.5	33.5 - 70.1	201.0	91.1 - 443.7
187	48.8	28.2 - 84.4	312.4	65.8 - 1483.5

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
111	51.8	45.7 - 58.6	1000.0	554.3 - 5381.9
134	57.1	18.9 -172.8	308.6	21.4 - 4459.7
179	58.3	39.3 - 86.4	NT	-
132	58.5	28.3 -120.6	306.7	59.3 - 1585.6
141	60.0	34.5 - 85.5	179.2	103.7 - 1826.9
168	67.4	19.3 -235.9	780.1	21.9 -27829.5
173	67.6	42.8 -106.9	780.6	206.2 - 2954.9
38	69.8	59.2 - 82.4	833.5	537.9 - 1291.3
139	71.5	38.5 -133.1	352.6	73.2 - 1694.3
231	71.9	41.2 -125.5	512.2	142.2 - 1844.6
113	75.6	68.0 - 84.1	783.5	570.2 - 1076.4
47	78.5	65.8 - 93.8	414.9	289.7 - 594.3
200	NT	-	NT	-
82	NT	-	NT	-
136	NT	-	NT	-
130	NT	-	NT	-
22	NT	-	NT	-
83	NT	-	NT	-
115	NT	-	NT	-
25A	NT	-	NT	-
116	NT	-	NT	-

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
171	NT	-	NT	-
193	NT	-	NT	-
169	NT	-	NT	-
118	NT	-	NT	-
30AC	NT	-	NT	-
174	NT	-	NT	-
176	NT	-	NT	-
131	NT	-	NT	-
41	NT	-	NT	-
44A	NT	-	NT	-
195	NT	-	NT	-
114	NT	-	NT	-
125	NT	-	NT	-
181	NT	-	NT	-
213	NT	-	NT	-
215	NT	-	NT	-
218A	NT	-	NT	-
219	NT	-	NT	-
220	NT	-	NT	-
221	NT	-	NT	-

Table 1. Cont.

LOCATION	EC-10 (% pore water)	CI EC-10	EC-50 (% pore water)	CI EC-50
223	NT	-	NT	-
224	NT	-	NT	-
226	NT	-	NT	-
229	NT	-	NT	-
232	NT	-	NT	-
51	NT	-	NT	-
129	NT	-	NT	-
142	NT	-	NT	-
54	NT	-	NT	-
59A	NT	-	NT	-
194	NT	-	NT	-

NT = Not Toxic; slope of probit line is not significantly different from zero or EC-50 estimate greater than 100%.

CI = 95% confidence interval.

Table 2. Predictive log-linear, probit equations, which relate inhibition of P. phosphoreum bioluminescence after 15 min. to % sediment pore water, extract. Only locations, for which the slope of the regression was significantly greater than zero, are reported.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
106	1.1767	1.7989
30UP	1.2443	1.7729
112	1.0523	2.7239
119	0.7290	1.7616
188	0.6136	3.5115
25	1.1644	3.5787
30CR	0.9594	3.1343
34	0.8727	3.0281
157	1.5844	5.0446
147	0.8564	3.4822
204	1.4485	4.8874
127	1.4576	5.0782
165	0.9321	4.2371
42	1.0820	4.6097
105	0.8290	4.0833
167	0.9156	4.2921
53	1.9875	6.6611

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
107	1.2415	5.0431
162	1.3369	5.3301
203	1.1887	5.0139
183	0.8756	4.3679
198	1.1345	5.0671
120	0.9518	4.5705
124	2.2138	7.4341
30	0.7657	4.1632
43	1.1080	5.0620
145	0.7062	4.2067
144	1.1012	5.0996
161	0.8856	4.6791
209A	0.9742	4.9284
137	0.9469	4.8793
143	0.9393	4.8947
189	1.1512	5.3950
211	0.7188	4.4498
191	0.9272	4.9201
227	1.4080	5.9940
20A	0.7456	4.5540

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
121	0.8316	4.7820
186	0.7723	4.6845
155	0.8935	4.9487
110	1.6740	6.0577
163	0.8858	4.9984
37	1.3614	6.0720
128	1.0940	5.5053
166	1.4662	6.3276
159	0.8672	5.0155
207	0.8467	4.9771
135	1.0680	5.4649
117	1.0887	5.5322
49	0.7940	4.8845
77	2.4704	7.1413
196	1.5671	6.6221
45	0.3904	4.0373
172	1.1749	5.7619
154	0.6535	4.6881
160	0.9497	5.3774
104	0.8731	5.2167
153	1.3781	6.3769

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
170	0.7786	5.1085
202B	0.3909	4.2716
214	0.6683	4.8825
52	1.2918	6.2545
208	0.5848	4.7011
202	0.7713	5.1223
228	0.8810	5.3860
192	0.6659	4.9498
209	0.9539	5.6798
158	1.3602	6.5057
126	0.3597	4.3093
212	0.5853	4.8740
59	0.7232	5.2298
197	0.7544	5.3054
213A	0.6040	4.9860
190	0.7737	5.4124
182	0.9481	5.8061
146	0.6011	5.0760
133	0.8095	5.5752
152	0.7453	5.4340
218	0.4550	4.8340

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
222	0.5830	5.1170
151	1.0910	6.2406
225	0.4940	4.9500
138	0.6474	5.3033
187	0.8446	5.7444
111	1.5957	7.4513
134	0.7681	5.7322
179	1.8403	8.1086
132	0.7540	5.7259
141	2.6560	5.9850
168	1.1141	6.6594
173	1.1128	6.6601
33	1.1281	6.7257
139	0.7252	5.8643
231	0.3930	6.2390
113	1.5167	6.6637
47	0.7573	6.0282
200	-	-
82	-	-
136	-	-
130	-	-

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
22	-	-
83	-	-
115	-	-
25A	-	-
116	-	-
171	-	-
193	-	-
169	-	-
118	-	-
30AC	-	-
174	-	-
176	-	-
131	-	-
41	-	-
44A	-	-
195	-	-
114	-	-
125	-	-
181	-	-
213	-	-

Table 2. Cont.

LOCATION	SLOPE (M)	INTERCEPT (b, log% extract)
215	-	-
218A	-	-
219	-	-
220	-	-
221	-	-
222		-
224	-	-
226	-	-
229	-	-
232	-	-
51	-	-
129	-	-
142	-	-
54	-	-
59A	-	-
194	-	-

Log EC_x = M probit + b

Where: Probit values are calculated from the % inhibition of bioluminescence (Finney, 1971).

EC_x = concentration of pore water extract to cause some proportion inhibition (x) of bioluminescence.

CI = 95% confidence interval.

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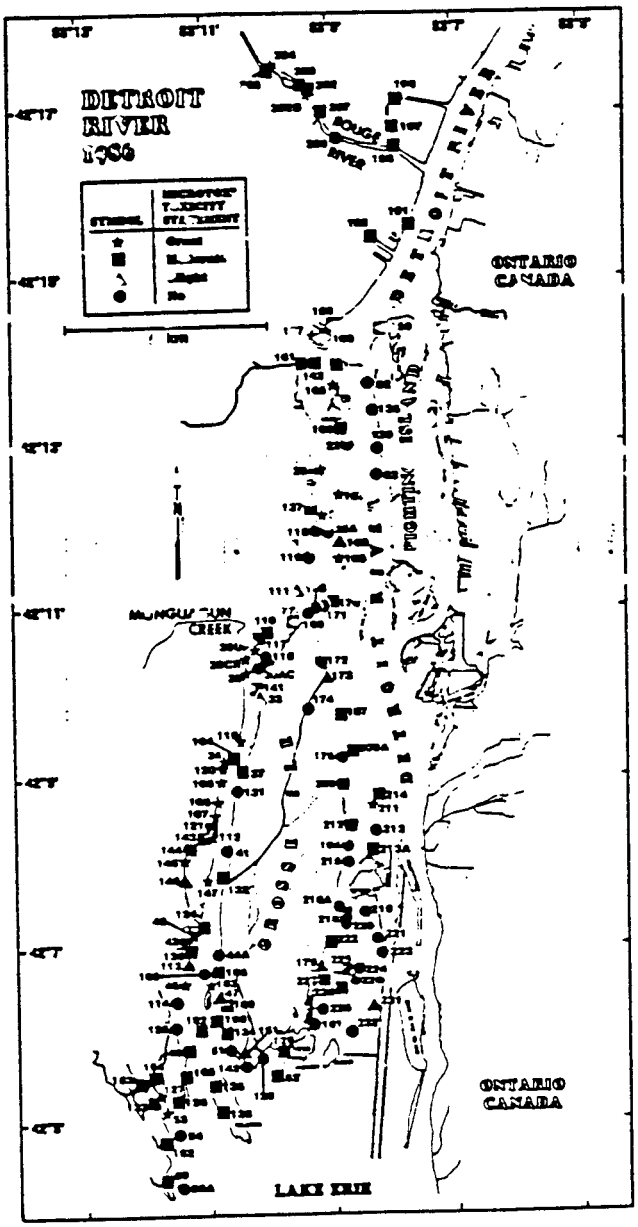
DETROIT
RIVER
1968
ONTARIO
CANADA
ONTARIO
CANADA
LAKE ERIE

Figure 1.

FIGURE LEGEND

Figure 1. Distribution of toxicity of pore water extracts, isolated from sediments collected from 136 locations in the lower Detroit River during the summer of 1986. The toxicity, as determined by the Microtox^{R}, microbial bioluminescence assay, was classified into four categories based on concentrations of pore water extract to elicit a 10% reduction in bioluminescence: Great, EC-10 < 10%; moderate, 40% > EC-10 > 10%; slight, 80% > EC-10 > 40% and non-toxic EC-10 > 80%.

ACKNOWLEDGEMENTS

This research was conducted as a cooperative agreement between the U.S. Environmental Protection Agency and Michigan State University, under agreement No. DL 85-002-06. Data analysis was supported by the Michigan Agricultural Experiment Station, from which it is contribution No. Manuscript preparation was supported by the Department of Ecological Chemistry and Geochemistry of the University of Bayreuth, Bayreuth, Germany under a grant from the Fulbright Commission. The authors wish to thank the following persons for technical assistance: J. Filkins, USEPA; C. Fomik, Michigan State University; J. Kuhbush, Raythion Corp.; M. Flexner, University of Michigan; D. Cessner; D. McDonald, R. Davis and N. Miller Michigan Department of Natural Resources. J. Thompson, typed the manuscript.